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Development of 3-D Printed Nanocarbon / Epoxy Polymer Composite

Ahmed Alhelal

DEVELOPMENT OF 3-D PRINTED NANOCARBON/EPOXY POLYMER COMPOSITE

Ahmed Alhelal, MS, BS

Materials Science | Mechanical Engineering

Saudi Arabian Culture Mission (SACM) Fellow

PhD Researcher - Tuskegee University

PRESENTATION OUTLINE

- Introduction
- Uniqueness of 3-D Printing
- Materials and Methods
- Advantages and Disadvantages
- Results
- Conclusions | Ongoing Work
- Acknowledgments | Contact

INTRODUCTION

- Resin moldings of various architectures created using 3-D printers
    - produced with nanoclay and other nano-carbon particles
    - proven to be brittle over time
- Crystalline carbon-infused epoxy polymer composites
    - fabricated from renewable source
- Carbon nanoparticles (CNP) made from spent coffee grounds (SCG)

OBJECTIVES

- Preparation and characterization of carbon nanomaterial from a sustainable source, SCG
- Manufacture composites using 3-D printing of epoxy resin modified by the as-prepared carbon nanomaterial
- Characterization of the prepared composites

APPLICATIONS

Automotive

Construction

Aerospace

Why 3-D Printing?

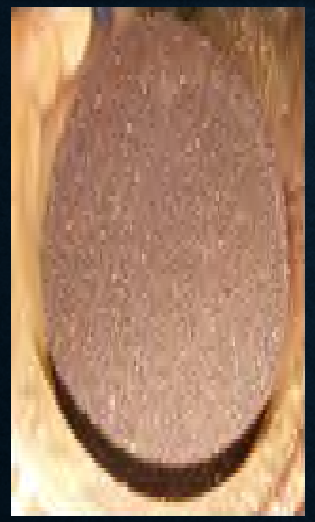
- Long-term sustainability
- Processes are operationally simple
- Flexibility; ability to print in bulk
- Create prototype products
- Less costly tooling changes

Uniqueness of 3-D Printing in Aerospace

- Manufacturing Speed
- Complexity and Design Freedom
- Customization
- Improved Strength and Durability
- Weight Reduction 40-60 %

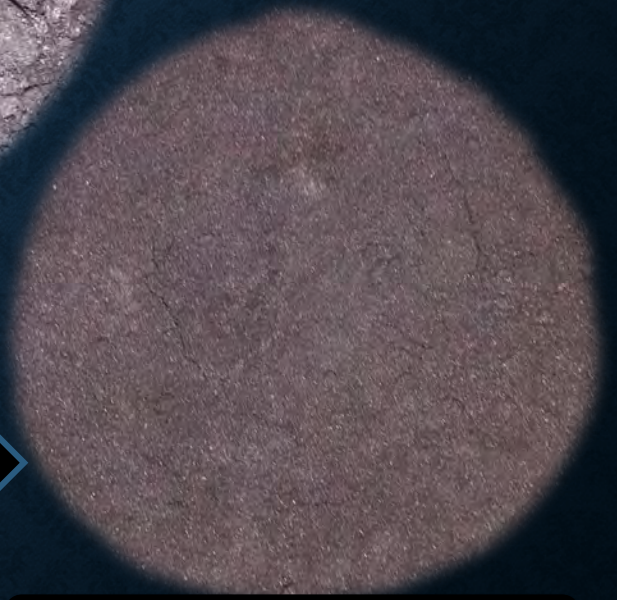
SYNTHESIS OF CARBON FROM SCG

Dried SCG



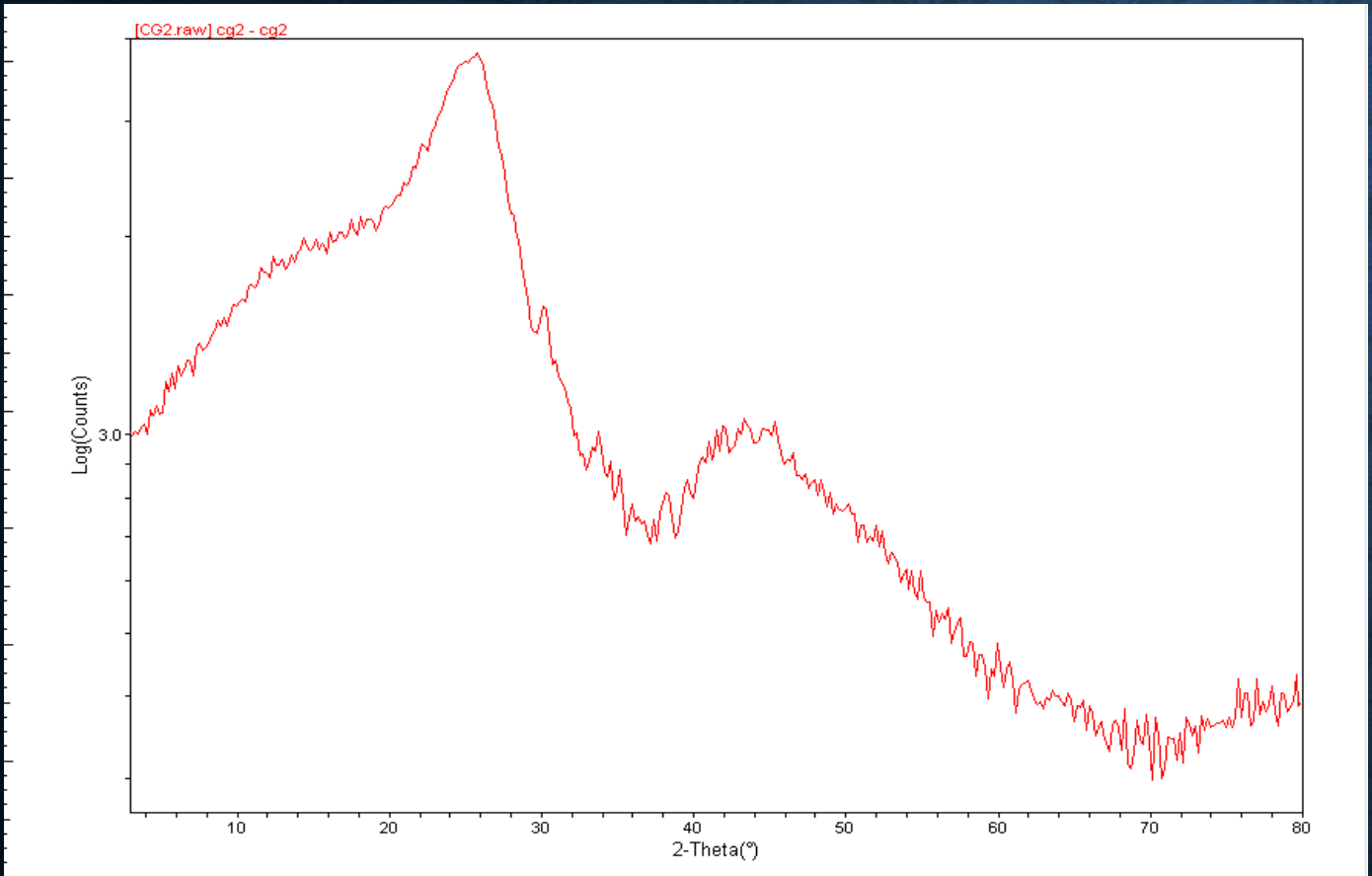
Pyrolysis at 800°C for 2 hrs

Carbon after pyrolysis



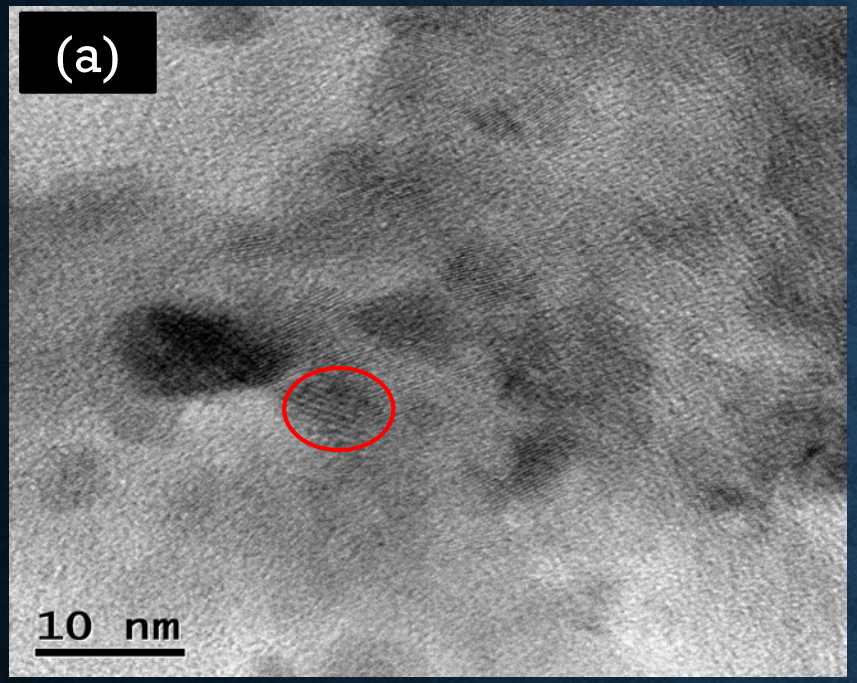
Carbon powder

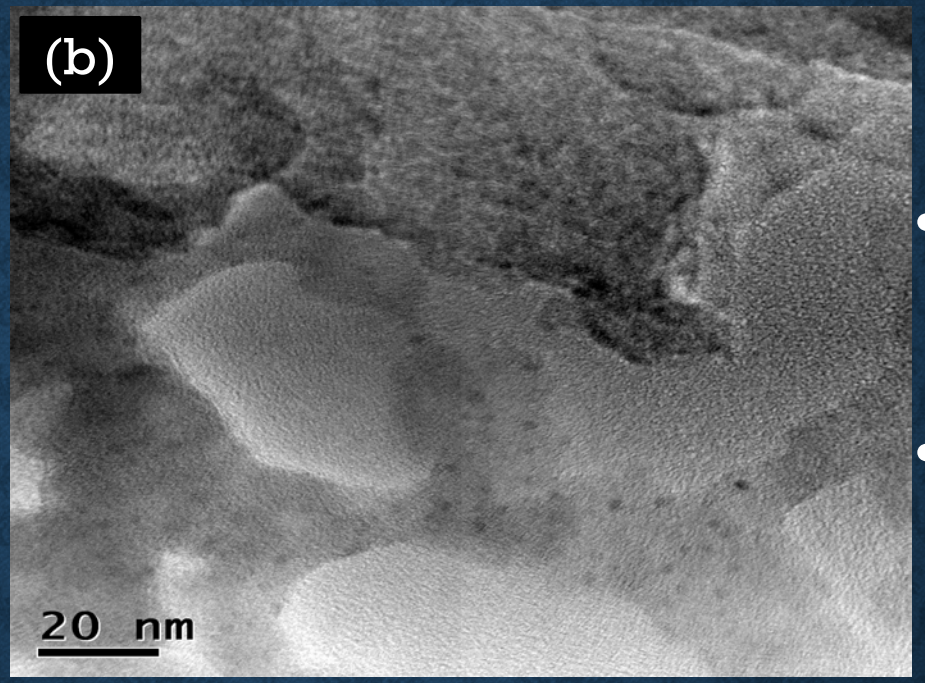
X-RAY DIFFRACTION (XRD)

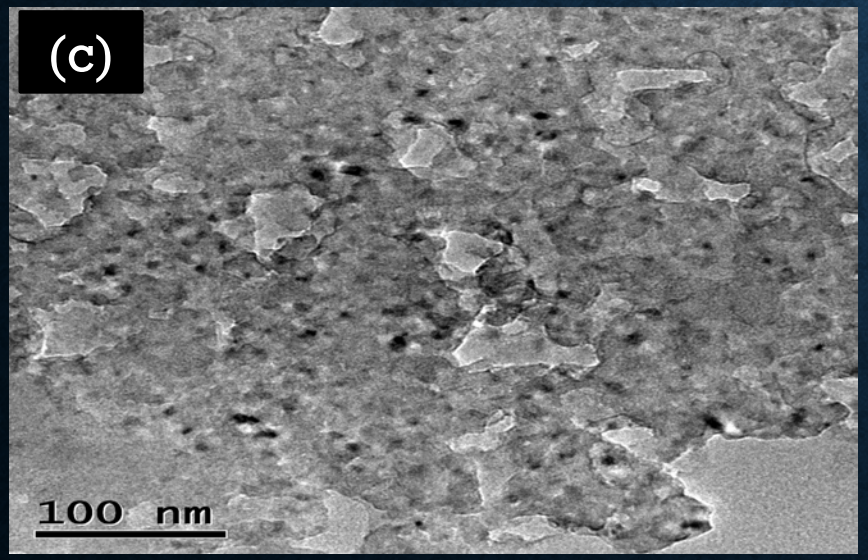


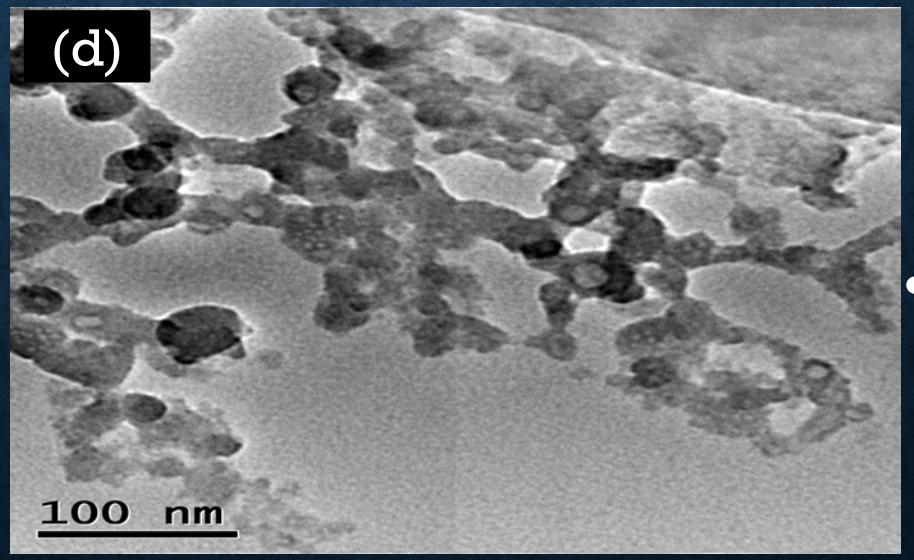
- The plot shows crystallinity at 25° and 45°
- Comparative to the chemically activated carbon sourced from the same material

TRANSMISSION ELECTRON MICROSCOPE (TEM)







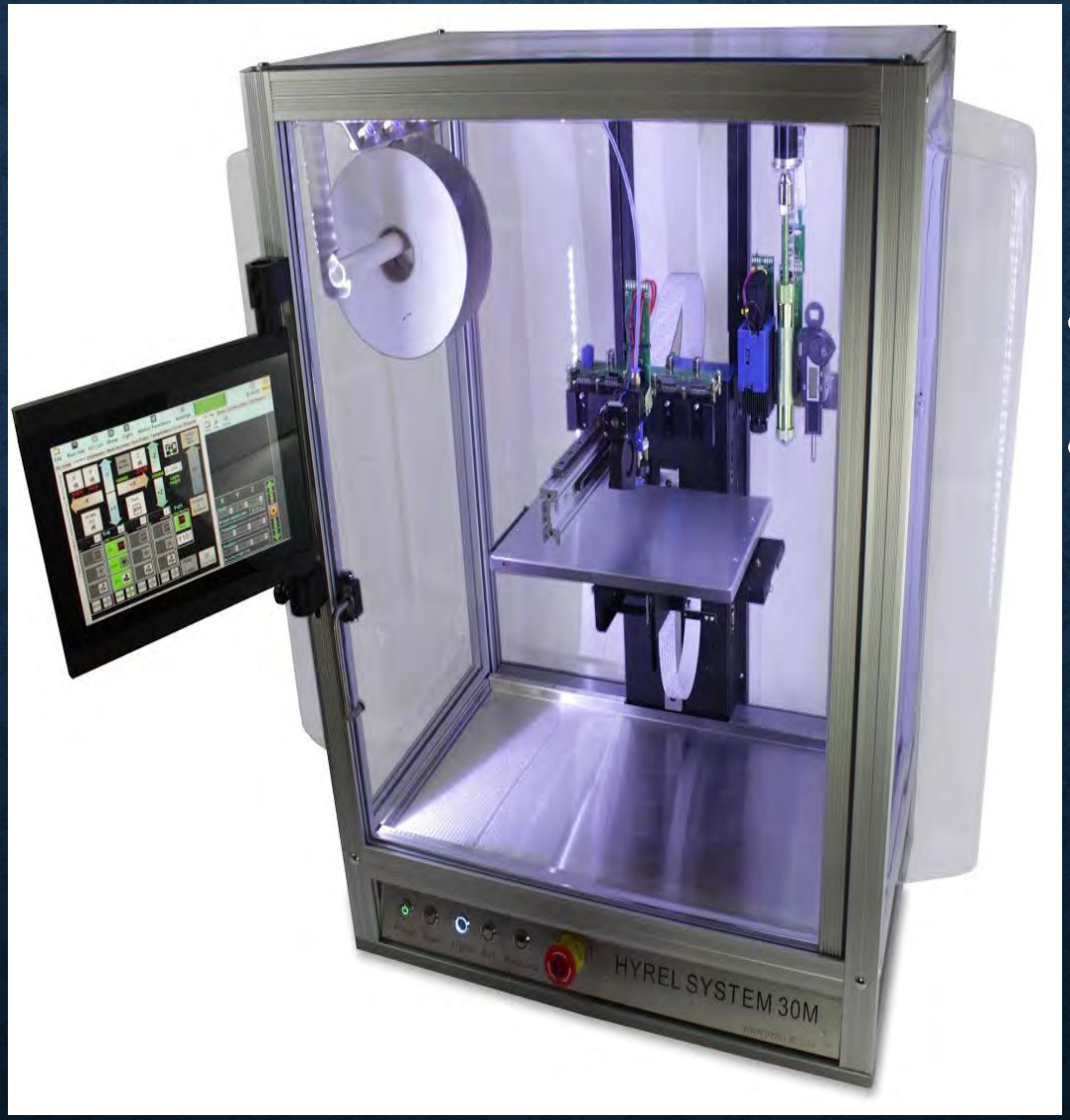


- Particles are crystalline
- Carbon particles
  - ~10 nm
  - spherical
  - Shape and sizes are suitable for fillers
- Carbon particles are highly porous

CUSTOMIZED 3-D PRINTING

Advantages

- Cost effectiveness
- Curing cycle
- Fillers



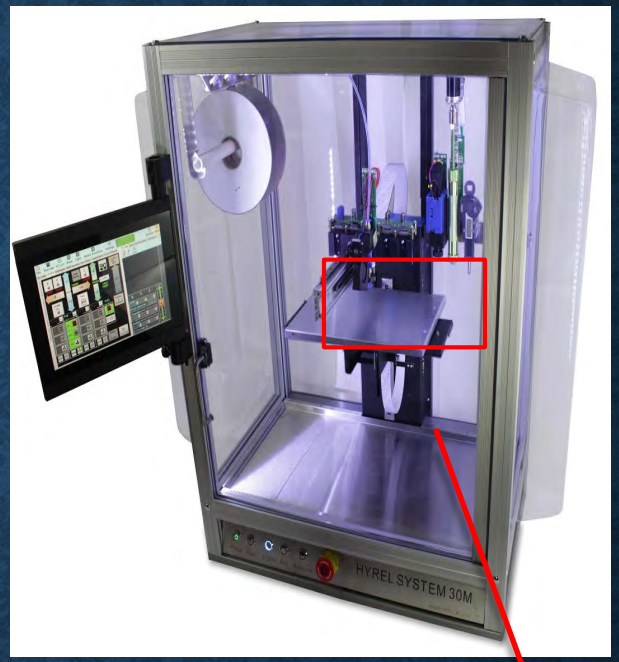
Disadvantages

- Solution printability
- Printing space

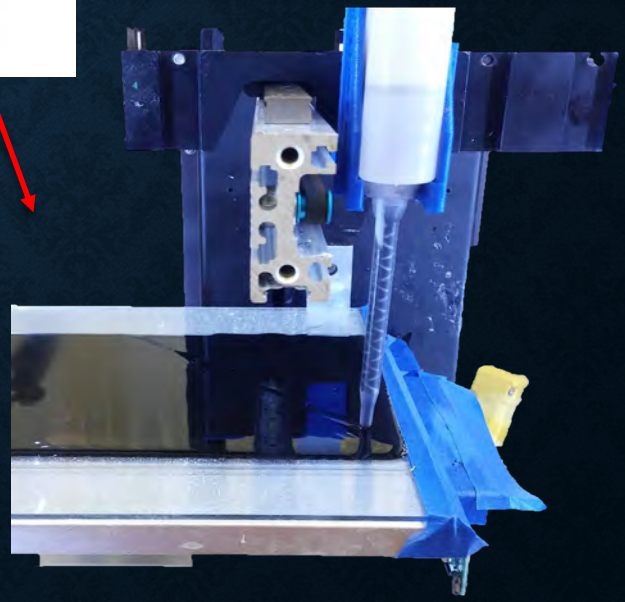
Protocol for 3-D Printing of Composites

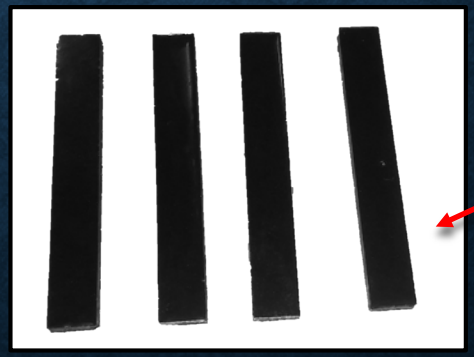
Sonicate SCG w/ 150 Thick Epoxy Resin for 1 hr with 30% amplitude

Addition of 1:1 Epoxy Hardener



Pour infused epoxy resin in a duel syringe and print for 5 hrs at 70 °C





Printed flexural samples

Flexural Test Analysis – 3-D

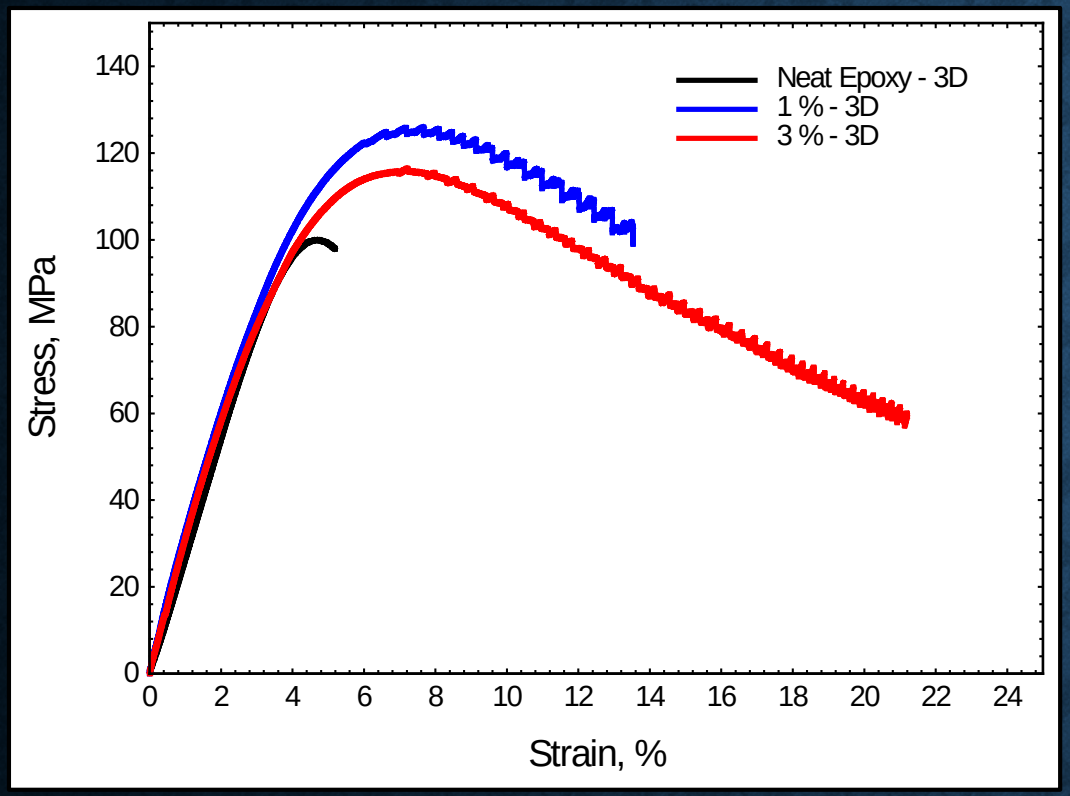
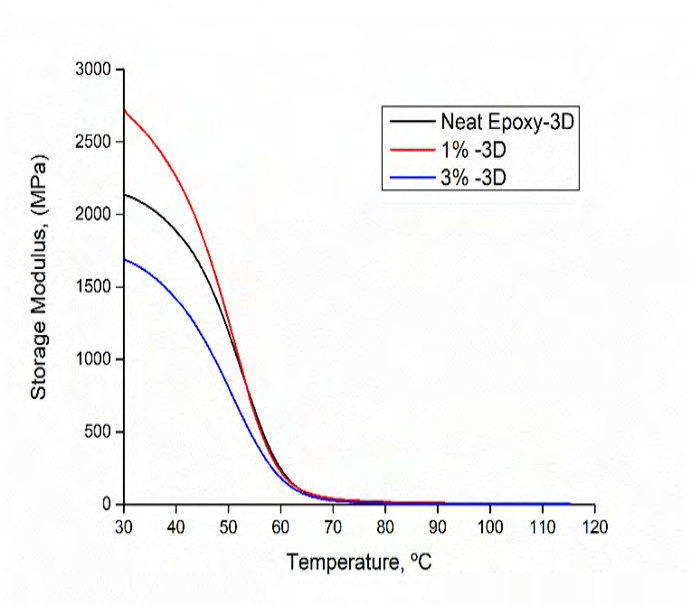


Table 5.1: Flexural properties of 3-D printed neat epoxy resin compared to composites prepared by adding 1 and 3 wt. % carbon nanoparticles to epoxy resin

Sample Name	Strain at maximum %	Flexural Strength MPa	Flexural Modulus GPa
Neat Epoxy	4.5	100.06	2.42
1% - 3D	14	125.93	5.88
3% - 3D	21.5	115.56	4.34

- The 1% loading has a higher flexural strength and strain than the neat and 3%
- Higher % of carbon loadings are not printable because of their high viscosity
- The optimum loading is ~1% for increased strength and 3% for increased ductility

DYNAMIC MECHANICAL ANALYSIS (DMA)- 3-D



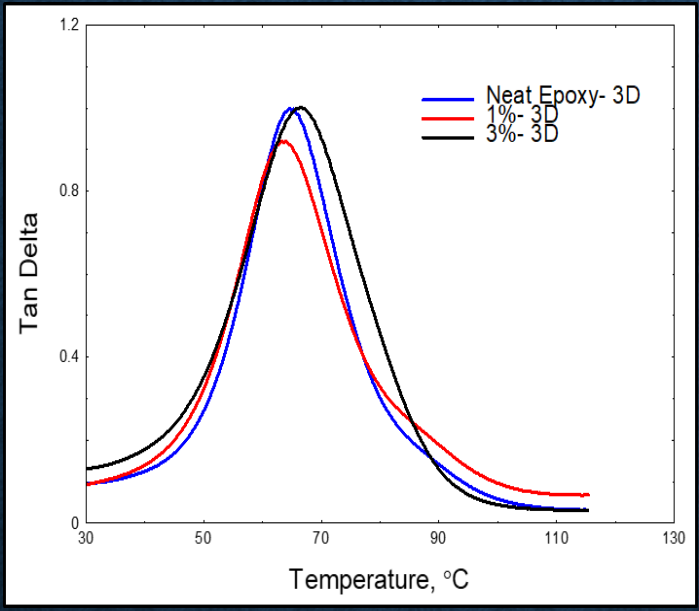


Table 5.2: Storage modulus and glass transition temperature (Tg) of 3-D Printed neat epoxy resin compared to composites with 1 and 3 wt. % CNP to epoxy resin

Sample Name	Storage Modulus (MPa)	Tg (°C)
Neat Epoxy	2131	65.32
1%	2716	63.29
3%	1687	66.36

- 1% carbon loading increased the storage modulus as compared to the neat and 3 wt. % loading

THERMAL MECHANICAL ANALYSIS (TMA) – 3-D

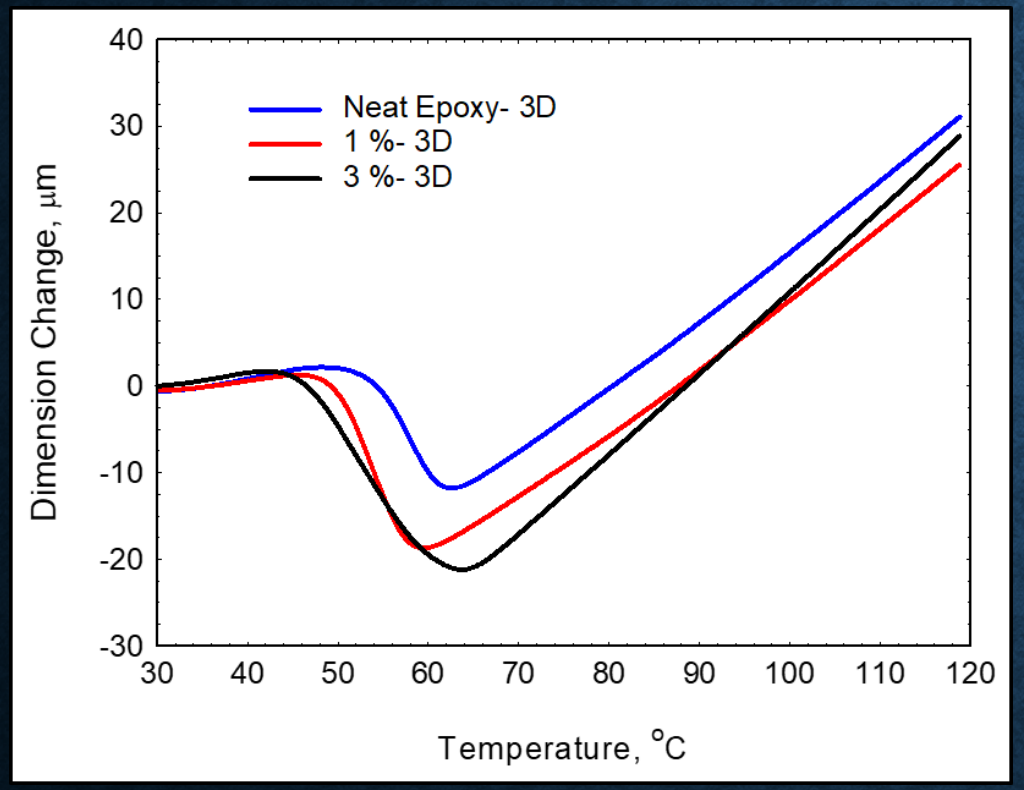


Table 5.3: Coefficient of Thermal Expansion (CTE) and of 3-D Printed neat epoxy resin compared to composites prepared by adding 1 and 3 wt. % carbon nanoparticles to epoxy resin

Sample Name	CTE before Tg (µm/m°C)	% change	Tg (°C)	CTE after Tg (µm/m°C)	% change
Neat Epoxy	43.68	-	57.82	195.50	-
1%	33.81	-15.11	53.78	198.00	1.28
3%	37.08	-22.60	52.47	208.90	6.86

- 1% loading of carbon nanoparticles decreased the CTE ~77% as compared to the neat polymer

CONCLUSIONS | ONGOING WORK

Conclusion

- The preliminary test results show 3 wt. % CNP loading increase in DUCTILITY

- 1 wt. % CNP increase FLEXURAL STRENTH over neat

Further studies to test:

- other epoxy resin systems without curing while printing
- increase nanoparticles percentage to determine mechanical properties
- enhance thermal conductivity
- improve printing methods of higher percentage nanoparticles loadings

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CONTACT

Ahmed Alhelal

Email: aalhelal5773@tuskegee.edu

Phone: (404) 998-0211

www.twitter.com/AhmedAlhelal8

www.linkedin.com/in/ahmed-alhelal/